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09/869710
430 Rec'd PCT/PTO 02 JUL 2001

[22750/492]

THREE-DIMENSIONALLY STRUCTURED FIBROUS WEB AND A METHOD FOR ITS MANUFACTURE

Description

Background of the Invention

The present invention is related to three-dimensionally structured fibrous webs.

By "three-dimensionally structured" is meant here fibrous webs in which the orientation and the spatial coordination of the individual fibers with respect to each other in any given surface plane diverge from those in the next closest surface plane.

In particular, the present invention relates to fibrous webs which have at least one nonwoven fabric layer, which is bonded to at least one layer made of an scrim, a lattice, or a netting.

A method for its manufacture is indicated.

Related Art

From U.S. Patent 4,302,495, fibrous webs according to the species are known.

One or a plurality of layers made of discontinuous, thermoplastic polymer fibers and one or a plurality of layers composed of an open-mesh netting made of coarse, thermoplastic, continuous melt-blown fibers, which cross each other at a preestablished angle, are bonded to each other by thermal fusing, either continuously or in spot fashion, to produce a web having a uniform thickness. The randomly running short fibers have a diameter of between 0.5 and 30 μm at a

weight per unit area of 10 to 15 g/m². Both the combination, lattice/microfiber layer/lattice, as well as microfiber layer/lattice/microfiber layer are described. A preferred material for both the microfibers as well as the filaments of the lattice is polypropylene. A web of this type has a very high tensile strength, together with a porosity that can be precisely adjusted. The melt-blown microfiber layers determine the external appearance and, for example, the filtering properties, whereas the thermoplastic netting(s) aid in reinforcement, controlling the porosity, and, if appropriate, simulating the appearance of a woven textile fabric. Therefore, the material is suitable not only for use as filters, but also as a sterile packing material in surgery. Further application areas are chemically inert filter media or non-wettable, light-weight, thermal insulating layers for clothing, gloves, or boots.

The thermal bonding of the layers to each other is carried out under pressure, for example, between heated rolls, one of which having the appropriate engraving if spot-bonding is desired. In addition, heat radiation can be applied before the heating is carried out between the rolls. The level of the heating effect is set so that the fiber materials soften without undergoing a temperature increase to the level of their crystalline melting point.

It was discovered that fibrous webs of this type do not stand up to pressure spikes or other powerful mechanical forces over a longer period of time without significant compaction, if, when packed, stored for extended periods, and transported, they are exposed to high pressures and temperatures up to 60° C, which is entirely usual in a shipment to tropical countries.

Objective

The objective of the present invention is to improve the

aforementioned three-dimensionally structured fibrous web of the related art so that it stands up to pressure spikes up to 1 psi acting perpendicular to the surface plane without being destroyed, even at temperatures up to 60° C.

In addition, the present invention indicates a method of manufacture for a fibrous web of this type.

Presentation of the Invention

The objective is achieved in a three-dimensionally structured multilayer fibrous web having the characterizing features of the first patent claim as well as in a method according to the first method claim. Advantageous embodiments are cited individually in the subclaims.

At least one nonwoven fabric layer is bonded, in each case, to one scrim layer. The nonwoven fabric layers are made up of fibers that are bonded to each other mechanically and/or thermally and that, in the surface direction, possess a fold-like pattern in the form of geometric, repeating elevations or undulations.

Present in the structure according to the present invention is at least one thermoplastic scrim, lattice, or netting layer having continuous filaments crossing each other and bonded at the crossing points by fusion, the filaments having a thickness of 150 to 2000 μm between their crossing points, and having thickenings at the crossing points of up to seven times these values. For reasons of simplicity, this layer hereinafter is always termed a scrim, even if other structures having crossing individual filaments are at issue.

The mesh size of the scrim, i.e., the distance in each case between two adjacent filament crossing points in the longitudinal direction, multiplied by the corresponding distance in the transverse direction, is 0.01 to 9 cm^2,

assuming that the filament crossing points in the longitudinal as well as in the transverse direction have a distance from each other that is not less than 0.10 mm.

The specific bond between fiber layers and the scrim layers can be continuous, spot-form, or linear- or continuous-patterned.

The continuous filaments of the scrim are made up, for example, of polyethylene, polypropylene, polyamide-6, polyamide-6.6, polybutylene terephthalate, polyethylene terephthalate, polyester elastomers, copolyesters, copolymers made of ethylene and vinyl acetate or of polyurethane.

In one advantageous embodiment of the present invention, the scrim is made up of a netting that is biaxially elongated. The elongation in the direction of both filament patterns is carried out in accordance with known methods in the longitudinal direction by passing through the gap between a slower moving and a more rapidly moving roll, the elongation ratio thus being determined by the ratio of the more rapidly moving to the more slowly moving rolls. In the transverse direction, the elongation is carried out using an expanding tenter frame.

This known method brings about a reduction in the thickness of the filaments between the mutual crossing points and therefore a reduction in the weight per unit area of up to 95%.

Laminated webs are also the subject matter of the present invention as a result of a single- or double-sided coating of fusion adhesive, which has a significantly lower melting point and adhesion point than the plastic of the filament.

In the context of the present invention, it is possible to carry out the single- or double-sided covering of the scrim using nonwoven fabric such that each nonwoven fabric layer has

different properties with respect to the configuration of its folds or with respect to its inherent properties, such as weight per unit area, type of fiber, and fiber bonding.

In general, in selecting the parameters for the nonwoven fabrics with respect to composition, type of fiber, fiber bonding, and fiber orientation, the worker skilled in the art is guided by the properties known to him that these layers are supposed to have. In the interest of a high inherent rigidity of the elevations and undulations, it is necessary for the nonwoven fabric fibers to be intensively bonded to each other.

If the fibers are fixed using a bonding agent, a bonding agent having a hard grip is preferable, because in this way the inherent rigidity and mechanical resistance of the fibrous web is increased overall.

In a further advantageous embodiment of the present invention, each of the nonwoven fabric layers that is present can have fibers that are fused in planar fashion, these fused surfaces being in each case thermally bonded to the scrim.

It is advantageous if the distance from one filament crossing point to the next one in the scrim, as well as the degree of elongation and the filament strength in the longitudinal and transverse directions, are approximately the same, because in this way, after the shrinking process, elevations are produced having a circular base cross-section. These have proven to be the most resistant to pressure loads exerted perpendicular to the surface plane.

Depending on the starting material selected, multilayer fibrous webs can be produced having weights of 20 to 3000 g/m^2. Products having lower weights per unit area are suitable, for example, for layers in diapers that absorb and distribute liquid, such as have up to 3000 g/m^2 for high-volume filter matting, which have a high retention capacity for the

filtrate.

The present invention is explained in greater detail on the basis of the Figures:

Figure 1 depicts the subject matter according to the present invention in a top view;

Figure 2 depicts a cross-section along the line A-A from Figure 1;

Figure 3 depicts a cross-section as in Figure 2, but using nonwoven fabric layers of varying types.

First, Figure 1 is described: here one of the possible embodiments of the present invention is represented in a top view. Composite 1 is composed of shrunk scrim 4 and both nonwoven fabric layers 2 and 3. They are bonded to the shrunk scrim but not to each other, such that, on both sides of the scrim, elevations 6 and depressions 7 are formed on the nonwoven fabrics. Between and beneath the elevations are located hollow spaces 12, 13, which are permeable to fluid media and which absorb particles and dust from them. The scrim is made up of monofilaments 5 that cross each other.

In Figure 2, a cross-section along the line A-A from Figure 1 is represented; nonwoven fabrics 2 and 3 in areas 8 of depressions 7 are bonded to monofilaments 5 of scrim 4 using adhesive.

Figure 3 depicts a shrunk composite of nonwoven fabric and scrim, the distance between filaments 5 of the scrim and peaks 9 of elevations 6 is designated as reference numeral 10. The depicted cross-section, in contrast to Figure 2, has an asymmetrical design. Nonwoven fabric elevations 8 extend only in one direction perpendicular to the surface plane of the scrim. The scrim filaments on one side bear a co-extruded fusion adhesive 11 having a significantly lower melting and softening point than the remaining mass of the scrim. The

nonwoven fabric is intensively bound to the scrim by fusion adhesive 11, position 11 simultaneously indicating the lowest point of depression 7. Position number 10 defines the distance between the scrim plane and peak 9 of elevations 6. The latter result in a marked surface enlargement, which results in increased absorption capacity for particles that are to be deposited. Hollow spaces 12 between elevations 6 of the nonwoven fabric and of the scrim plane, oriented perpendicular to the surface plane, as well as open spaces 13 between depressions 7 and peaks 9 of elevations 6 are large enough to spontaneously absorb liquids of low- and medium-viscosity as well as multi-dispersion systems composed of solid particles and liquid solutions and possibly to convey them to absorbent layers situated below.

The method for manufacturing the three-dimensionally structured fibrous web is carried out by covering, in a planar fashion, a 3-300 g/m^2 heavy, unshrunk scrim, netting, or lattice made of thermoplastic continuous filaments with a nonwoven fabric on one or both sides and by bonding using generally known laminating techniques to form a planar nonwoven fabric. The nonwoven fabric can have been produced using all known measures, i.e., dry using combing, carding, or air exposure technology, using wet deposition, or using fibers that are spun from the melted mass, or continuous filaments. Subsequently, the composite is subjected to a thermal treatment, which is sufficient for the scrim to undergo a surface shrinking. The nonwoven fabric layers, which themselves undergo either no surface shrinkage or one that is significantly less in comparison to the scrim, give way perpendicular to the surface plane, forming elevations. The nonwoven fabric can be bonded generally either over the entire surface or over a partial surface. Perforated nonwoven fabrics can also be used for the method according to the present invention.

As a result of a further increase in temperature, the scrim in

the nonwoven fabric is made to shrink. The shrinking temperature is determined in accordance with the softening and melting range of the thermoplastics on which the scrim is based. To trigger a shrinkage, the temperature must lie between these two temperatures, the amount of shrinkage becoming higher the closer the temperature current actually affecting the knitted fabric approaches the melting temperature of the thermoplastic. Of course, the worker skilled in the art knows that, at the preestablished shrinkage temperature, the duration also exerts an influence on the extent of the surface shrinkage. The attainable amounts of shrinkage in the longitudinal and transverse directions, and the ratio of both amounts to each other, can be substantially predetermined by the choice of the scrim. Assuming an unhindered shrinkage free of contact, the ratio of longitudinal and transverse shrinkage is 1:1 if the monofilaments of the scrim have the same titer and the same rate of stretching in the longitudinal and transverse directions. If a different shrinkage is desired in the longitudinal and transverse directions, then knit fabric are selected whose monofilaments have been streched differently in the longitudinal and transverse directions, or whose titers turn out to be very different given the same degree of stretching. Scrims can also be used whose monofilaments in the longitudinal and transverse directions are created from different thermoplastics. In this case, the degree of shrinkage and the direction of shrinkage are determined by the components of the scrim, softening at a deeper level, a shrinkage temperature being selected which lies between the softening and the melting temperatures of the lower-melting components of the scrim.

The nonwoven fabric bonding and the lamination onto the scrim can also be carried out in one single step. Economy argues for this method. In this case, the scrim is positioned between two loose nonwoven fabric layers, it is subsequently needled mechanically or using water jets, yielding a composite, and it

is acted upon by bonding agents using known impregnating technologies.

As a nonfibrous bonding agent, liquid plastic dispersions are used, which are imprinted upon the composite either on one or on both sides, or a complete impregnation is carried out using a foamed mixture in a foam impregnating device or using an unfoamed mixture in a complete bath impregnation using the liquid plastic dispersions. Subsequently, drying is carried out and the bonding agent is cured in the heat.

As a result of the thermoplastic activation of the adhering fibers within the nonwoven fabric, additional interior reinforcement can be generated.

In the case of high-pressure water jet needling, in one particular embodiment of the present invention, the opportunity exists at the same time to generate perforations in the nonwoven fabric.

The ratio between longitudinal and transverse shrinkage determines the shape of the elevations in the nonwoven fabric layers. In a longitudinal/transverse ratio of 1:1, cone-shaped elevations arise that have, ideally, circular bases. In a longitudinal/transverse ratio not equal to 1, elevations arise having, ideally, oval cross-sections parallel to the base. If the shrinkage is completely prevented, for example, only in the longitudinal direction, in the longitudinal pattern, continuous, groove-shaped elevations are formed on the nonwoven fabric, which, ideally, have the same amplitude over their entire length.

It was surprising that scrims having weights under 10 g/m^2 can be shrunk to up to 80% of the starting length despite the nonwoven fabric covering on both sides having weights of at least 7 g/m^2. It would have been expected that the nonwoven fabrics would prevent the shrinkage of the scrim, especially

at the low starting masses per unit area of the scrim. However, this is not the case.

The following method variants have proven to be especially advantageous for reasons of simplicity:
The scrim is covered on one or on both sides with an unbonded nonwoven and is subjected to a thermal embossing-calendering or ultrasound calendering. The resulting, planar, two- or three-layer fabric has sufficient bond strength. Subsequently, without using a bonding agent, the shrinking is carried out thermally or using water vapor. For these method variants, bicomponent fibers are used having a side-by-side, eccentric or concentric core/sheath structure. The nonwoven fabric covering(s) can be made 100% of this bicomponent fiber or it can be used in a blend using thermoplastic and/or non-thermoplastic homofil fibers. With respect to the choice of homofil fibers, no limitations are necessary.

The melting point of the bicomponent fibers, in comparison to the lower melting components, must be lower or equal to the melting point of the individual scrim filaments that trigger the shrinkage. It is expedient if the melting point difference is not greater than 40° C to prevent the nonwoven fabric layers from becoming very brittle.

Even if the use of thermoplastic polymers contributing to the melting bonding is not critical, it has proven to be advantageous, in a single-side nonwoven fabric covering, to use melting components which have a chemical similarity to the thermoplastic polymers of the scrim. Otherwise, the danger arises of a poor bond strength after the lamination. In this connection, it is advantageous, for example for a scrim made of polyethylene terephthalate filaments, to use in the nonwoven fabric, polyester bicomponent fibers having copolyesters or polybutylene terephthalate, which melt at over 200° C as the sheath components.

Especially if the scrim and the nonwoven fabric are supposed to be bonded using thermal embossing-calendering or ultrasound reinforcement, it is advantageous to cover the scrim on both sides with nonwovens. After the calendering, both nonwovens above and below the scrim are bonded to each other in their open areas in a pattern. The scrim in this way is inserted into the composite so as to be inseparable. The number of thermal bonding points between the nonwoven fabric and the scrim in this unshrunk half-finished material is very low to the point of being negligible. The engraved surface of the embossing roll amounts to 4-30% of the entire contact surface.

In particular in the case of a slight difference in the melting temperatures between the scrim and the shell components of the bicomponent fibers, engraving rolls are preferably used having a bonding surface of only 4-14 % of the entire surface.

The manufacture of the unshrunk layer material made of nonwoven, scrim, and a further nonwoven can also be carried out between two heated, smooth steel rolls under pressure.

During the shrinking, the original bonds in the nonwoven fabric are dissolved from a great extent to entirely, so that no resistance is presented to the shrinking of the scrim. Only during the cooling does a new bond arise between the nonwoven fabric fibers.

The shrinkage is already triggered by a thermal treatment that occurs only once. Once it has been shrunk and cooled, the laminate cannot once again be brought to the point of shrinking by a second thermal treatment.

The multilayer, three-dimensionally structured fabric web according to the present invention can be composed of nonwoven fabric and scrim, in alternating fashion. The nonwoven fabrics on both sides of the scrim can be equal or unequal both in

construction as well as in weight. In special cases, it is also possible to provide for interior layers made of two nonwoven fabrics adjacent to each other.

The structured fibrous web can be used in all areas in which a high specific surface and a high fluid throughput are present along with a large particle retention capacity or a high compression strength in response to mechanical loads, especially at increased temperatures. Examples are filters as well as hygiene or medical products. The products according to the present invention can also be used for decorative purposes around the house, such as wall coverings.

Example 1

A biaxially elongated plastic netting made of polypropylene continuous filaments, having a weight of 7.8 g/m^2 and a mesh width of 7.6 mm x 7.6 mm, is positioned between two cross-laid, loose, staple nonwovens each having a weight of 10 g/m^2 and is conveyed to a spot welding reinforcement by calendering between a smooth and an engraved steel roll. The welding surface of the engraved roll amounts to 9.6% at an engraving depth of 0.73 mm. The calendering process takes place at a temperature of 140° C and at a line pressure of 30 kp/cm at a through-flow speed of 6 m/min. The width of the fabric is 50 cm.

The nonwoven fabric is composed of 90% core/sheath fibers having a core made of polyethylene terephthalate and a sheath made of copolyester, which melts at 120° C. The rest is viscose staple fiber. The titer of the core/sheath fiber amounts to 4.8 dtex and its cut length is 55 mm. The titer of the viscose staple fiber amounts to 3.3 dtex at a cut length of 60 mm.

The three-layer, planar fibrous web having an overall weight of 27.8 g/m^2 is subsequently subjected to a thermal shrinking treatment in a belt dryer at 170° C and a duration of 2 min

and 20 s. The original 50-cm-wide half-finished material after the shrinkage and cooling has a width of only 16 cm and a weight per unit area of 20 g/m². From this can be calculated a linear shrinkage in the transverse direction of 68%, a surface shrinkage of 76.8%, and a linear shrinkage in the longitudinal direction of 27.6%.

The mathematical formulas for the shrinkage calculation are:

$$S_{\square} = \left(1 - \frac{G_v}{G_n}\right) \cdot 100\,[\%]$$

$$S_q = \left(1 - \frac{b_n}{b_v}\right) \cdot 100\,[\%]$$

$$S_L = \left(1 - \frac{G_v \cdot b_v}{G_n \cdot b_n}\right) \quad [\%]$$

G_v Weight per unit area before shrinkage in g/m²
G_n weight per unit area after shrinkage in g/m²
b_v width of the fabric before shrinkage in m
b_n width of the fabric after shrinkage in m
$S_{\square}$ surface shrinkage in %
S_q linear shrinkage in the transverse direction in %
S_l linear shrinkage in the longitudinal direction in %

In the following table, the thicknesses are represented, measured under varying loads at room temperature and after a storage time of over 48 hours at a load of 1 psi. Using the formulas indicated below, compression resistance K is calculated in addition to rerecovery W, and creep resistance KB, each expressed in %. The thickness measurement for calculating the creep resistance is carried out at 0.2 psi contact pressure.

The thickness measurements were carried out as follows:
The sample was subjected for 30 seconds to a contact pressure of 0.6205 kPa psi and the thickness value was read out after the 30 seconds had elapsed. Immediately thereafter, the contact pressure was increased on the thickness measuring device to 1.3789 kPa by changing the weight, and the thickness was also read out after a further 30 seconds at precisely the same measuring location.

The same process was repeated, in each case for 30 seconds, in the sequence of contact pressures 3.4473, 6.8947, and again 0.6205 kPa.

To determine creep resistance KB, the test sample was subjected for 48 hours to a pressure of 1 psi at 60° C, and thereupon the thickness was determined at the contact pressure of 1.3789 kPa.

KW, W, and KB are calculated as follows:
The value for KW is obtained by dividing the thickness at 6.8947 kPa by the thickness at 0.6205 kPa and multiplying by 100 (result in %).

The value for W is obtained by dividing the thickness at 6.8947 kPa, at the completion of the measuring cycle, by the previously measured value at 6.8947 kPa and multiplying by 100 (result in %).

The value for KB is obtained by dividing the thickness of the test sample that is pressed at 60° C for 48 hours at 6.8947 kPa by the thickness of the unpressed test sample, in each case measured at 1.3789 kPa, and multiplying by 100 (result in %).

Unpressed layer construction	
thickness at	
0.6205 kPa	4.996 mm
1.3789 kPa	4.560 mm
3.4473 kPa	4.168 mm
6.8947 kPa	3.547 mm
0.6205 kPa	4.318 mm
KW (%)	71.00
W (%)	86.40

Pressed fibrous web at 60° C for 48 hours	
thickness at	
1.3789 kPa	2.485 mm
KB (%)	53